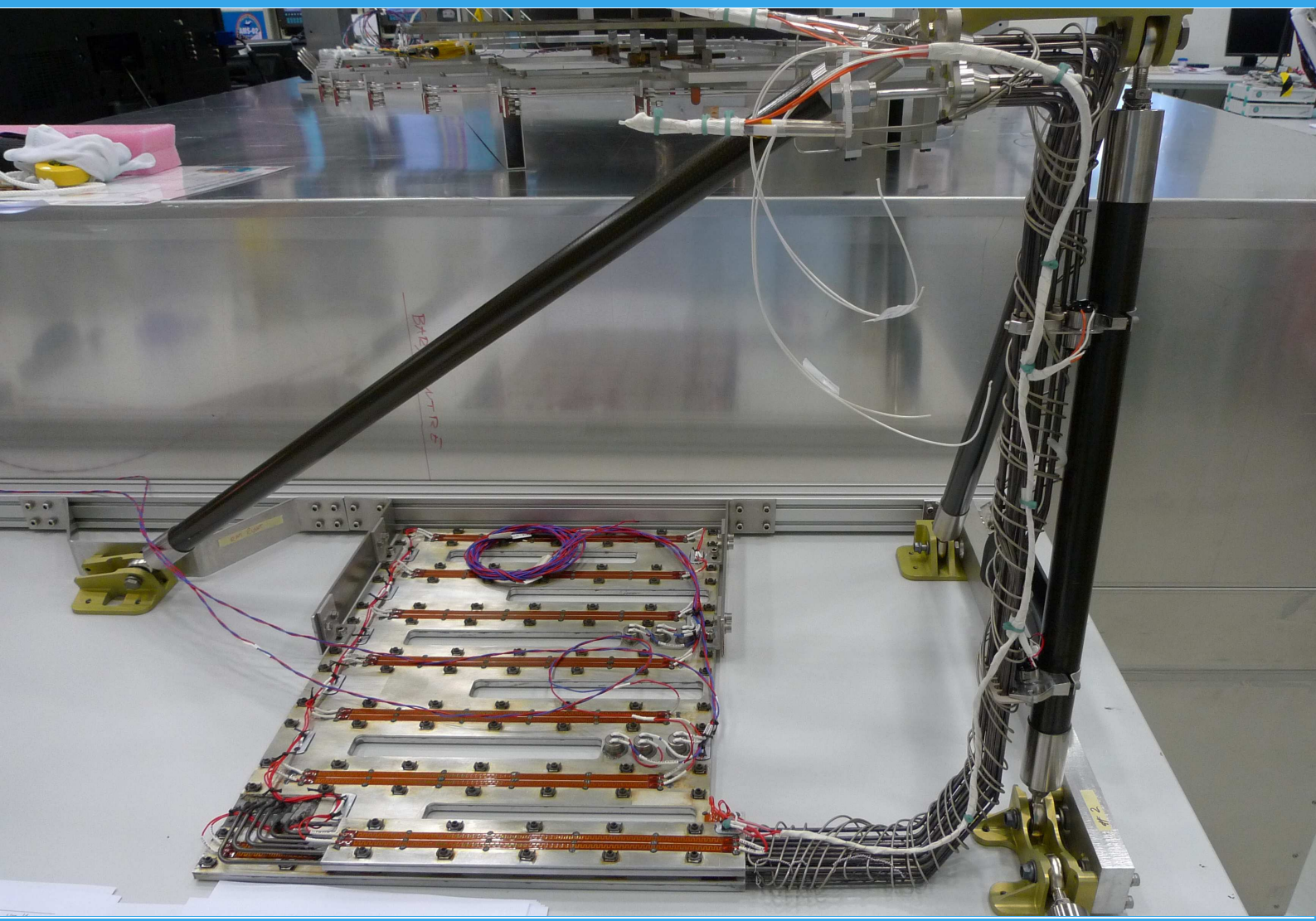
NLR Proposal TTCS Condenser Heater Design Verification Test

NLR PROPOSAL
for MIT

5339 - 15 December 2009



NLR – Dedicated to innovation in aerospace

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Contents

1 Introduction

Within the Alpha Magnetic Spectrometer experiment AMS02 (http://ams.cern.ch) the Tracker experiment is thermally conditioned by the Tracker Thermal Control System (TTCS). The AMS Tracker Thermal Control System (TTCS) is a two-phase cooling system developed by NLR (The Netherlands), INFN Perugia (Italy), Sun Yat Sen University, Zhuhai (China), AIDC Taichung, (Taiwan), Massachusetts Institute of Technology (USA), and NIKHEF (The Netherlands). The TTCS is a mechanically pumped two-phase carbon dioxide cooling loop. Main objective is to provide accurate (< 3 K) temperature control and remove the 140 W heat of the AMS02 Tracker front-end electronics.

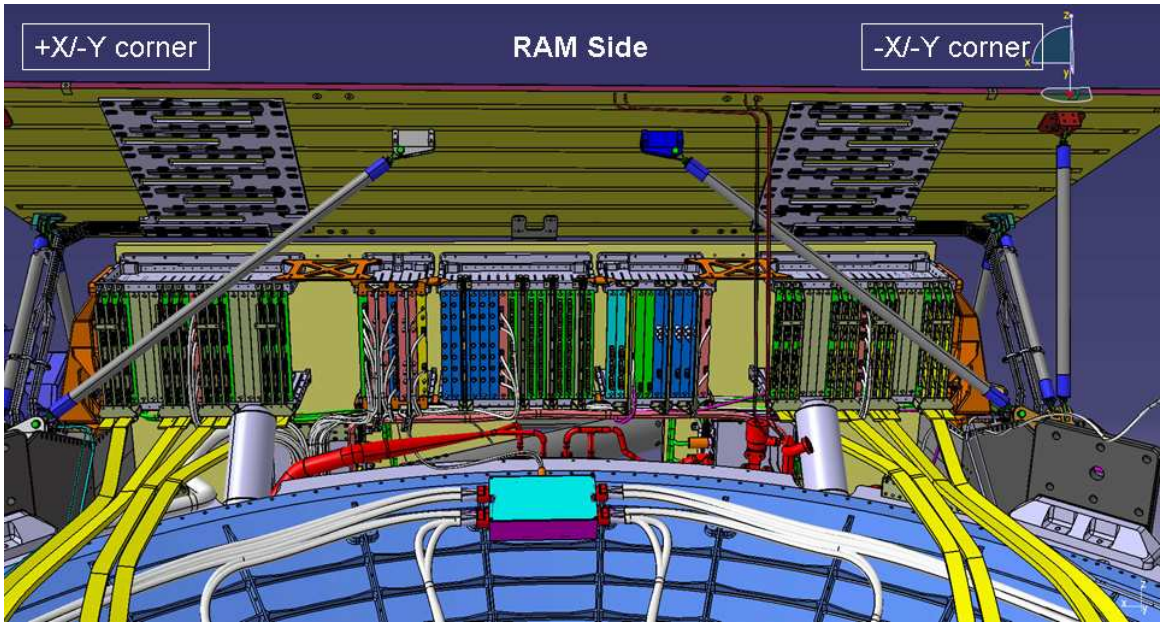


Figure 1: TTCS Condensers at the RAM radiator (picture by F. Cadoux

Two important components of each of the two TTCS loops are the TTCS condensers located on the Tracker radiators. In the condensers the vapour CO_2 is condensed to liquid and the heat is dumped into space by radiation.

As the CO_2 melting temperature is -55 ºC and the condensers are located on the outside of the AMS02 experiment CO_2 can freeze in an AMS02 power down situation. To recover from such a situation heaters are located at the Tracker radiator and condensers. Also the condenser inlet and outlet are equipped with heaters to melt the CO_2 in the inlet and outlet lines of the condensers. The heater design is shown below. Heater design details can be found in AMSTR-NLR-TN-043 TTCS heater specification.

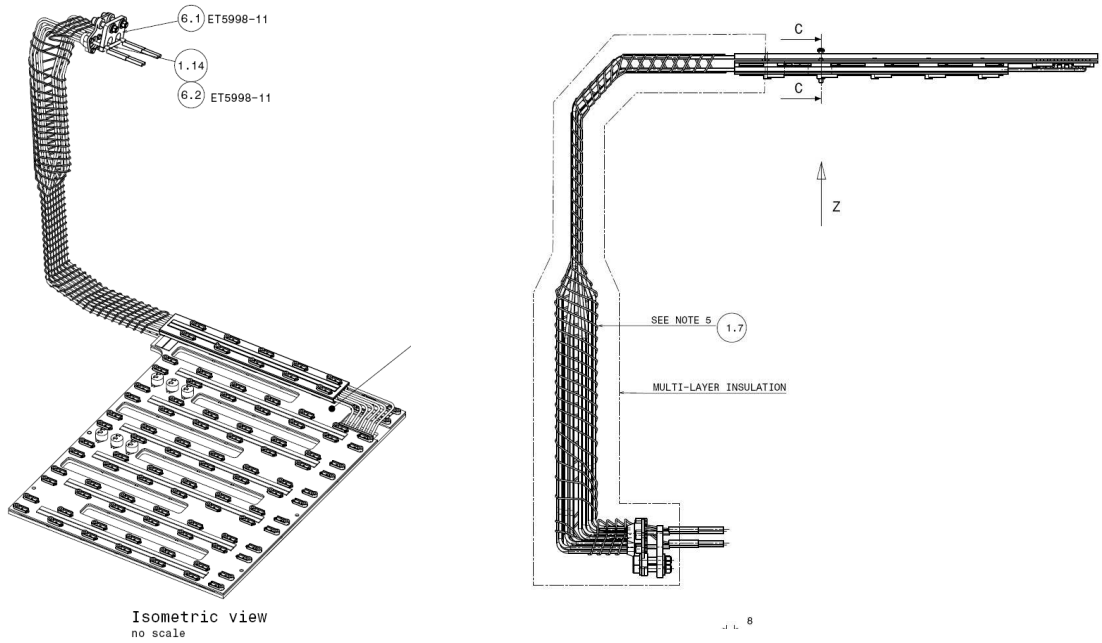


Figure 2: Condenser with condenser liquid line heater wrapped around the inlet and outlet and MLI volume

This proposal describes the activities required to verify the condenser 28V heater design by test in the NLR TV-chamber.

2 Test Objectives

The test objectives are:

1. Verification of the temperature increase of the condenser inlet and outlet tubes
    a. Measure the tubes temperature (determine time constant)
       It need to be verified whether the radiation heat transfer to the tubes is sufficient
    b. Measure the heater wire temperature
       Verification of the maximum heater wire temperature (MLI specification)
2. Verification of the largest temperature difference on the tubes during heating
    a. Largest temperature between wire heater-condenser tube touch point and a cold point on the tubes
    b. Safety verification lowest point is > -55ºC when touch point reaches -5 ºC
3. Verification of the condenser brackets temperature
    a. Simulate the thermal switches to protect the carbon fibre Tracker rods
4. Measure the heat leak of the condenser lines

Additional to this, the test could be used to verify the INFN/CGS thermal model of the condenser line heaters. However this is not part of this proposal.

3 Item under test

The tests will be performed with the TTCS QM condenser equipped with flight heaters and a representative MLI. TTCS QM condenser is an exact copy of the FM condensers with the following exceptions:

- A limited number of 120 V heaters are attached to the condenser surface
    a. No impact on the test with the 28 V heaters
- QM Condenser brackets are slightly different
    a. As the main purpose is to check the radiative heat transfer this difference can be accepted.
- QM condenser is attached to a stainless steel frame not to Tracker rods
    a. The stainless to stainless contact resistance is equal or higher than the stainless to carbon fibre resistance. The effect creates a worst case. The difference is acceptable to draw conclusions.

4 Test facilities

The test will be performed in the NLR Thermal vacuum chamber. The facility is described in Appendix A.

5 Work breakdown

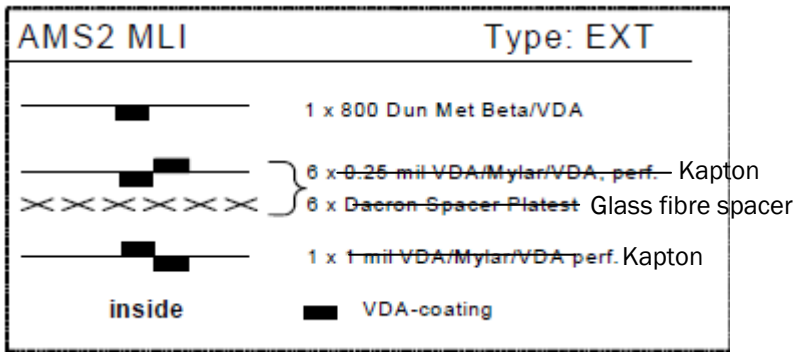
The work is divided into three work packages. WP100 comprises the test and facility preparation, WP 200 concerns the test execution and reporting. Both tasks will be done by NLR. In a separate WP 300 the MLI manufacturing is allocated. This task is performed by RUAG Space GmbH Vienna, AUSTRIA.

- **WP 100 Test preparation (NLR)**
    - Facility preparation
    - Procedure preparation
    - Preparation of QM condenser
        - Wrap and attach heater wire to condenser
        - Install MLI around condenser inlet/outlet tubing
        - Install Pt1000 at flight control locations
        - Install Thermocouples at reference points
            - Thermal switch locations
            - On tubes
            - On wire heaters
            - On brackets
            - Inside & Outside MLI
    - Implement on/off control based on Pt1000 location for nominal operational
    - Implement on/off control of heaters based on TC measurement on thermal switch locations (safety switches)

- **WP200 Test execution and reporting (NLR)**
    - Perform reference heating test in ambient conditions
        - Check for major flaws
    - Perform test in thermal vacuum chamber
        - Perform cooling down cycle to -80 C and monitor gradients
        - Perform heating with Pt1000 control until control point is reached
            - Nominal control set-point is between [-32 C, +31 C]
        - Perform further heating with control based on Thermal Switch location temperature
            - Thermal switch set-point (opening +54 C, closing +32 C)
        - Repeat the same test once
    - Reporting
        - Provide report including at least:
            - Gradient information
            - Maximum temperatures MLI, heaters, tubes
            - Recommendations for TTCS operation set-points

- **WP300 MLI manufacturing test sample and Flight Models (RUAG)**
  - Provide high temperature **Test sample blanket** for the condenser test.
    The QM condenser is like the Primary Wake/Secondary RAM so similar to the lay-out Blanket TTCS tubes Wake XP: G4370 -110-780 (=G4370-110-765)

  - High temperature blanket should have a lay-up as shown below:



  - The MLI will be procured at RUAG located in Vienna Austria.

5.1 Deliverables

Documents	WP ref	Resp	Delivery date
TTCS Condenser thermal vacuum test procedure	100	NLR	KO+4 days
TTCS Heater Design verification test report	200	NLR	FR
TTCS MLI test sample	300	RUAG	KO+4 days

6 Project team

The work will be performed by the NLR Space TTCS project team (Mr. A. Pauw, Mr. G van Donk, Mr. W. de Grave and Mr. J. van Es) at the NLR space department. The TTCS team will be supported by other NLR departments and workshops when needed. The MLI (WP300) is procured at RUAG Space GmbH Vienna, AUSTRIA.

7 Cost, Schedule and contractual aspects

7.1 Price Breakdown

A price breakdown is presented in Table 7-1.

WP	Man hours	Fac. hours	Costs (Euro)
WP 100 Test preparations	62		6,640.-
WP 200 Test & test reporting (including facility costs)	51	48	9,980.-
WP 300 MLI Manufacturing Procurement costs			7,000
Total	**113**	**48**	**23,620.-**

Table 7-1: Costs per WP

The activity is offered for:

Firm Fixed Price € 23,620 Euro (excl. VAT)

The Price is for all deliverables Delivered Duty Paid (DDP), exclusive of import duties and VAT in accordance with the INCOTERMS 2000. The proposed payment schedule is shown below.

Milestone	Date	Percentage	Payment
Final delivery	07-01-2010	100%	**€ 23,620.-**

Payment should be in accordance with the payment paragrapgh 8 of the NLR general conditions for small and medium sized project (Appendix B of this proposal). Payment is expected within 30 days after invoice date.

7.2 Test Duration, Schedule & Assumptions

Estimated test preparation for is 4 days. The test duration is estimated on 3-4 days. The manufacturing of the test MLI sheet will be started after KO by mutual agreement of the customer and subcontractor. The activities will be started as soon as this proposal is signed by MIT.

7.3 Contractual aspects

7.3.1 General Conditions

The General Conditions of NLR for small and medium sized projects are applicable and attached in the **ANNEX** of this proposal. NLRs liability for this contract is restricted to €10.000. (General conditions 7.1)

7.3.2 Validity of this Proposal

This Proposal remains valid for acceptance until 31 December 2009. NLR trusts that the proposed work, the quoted price, the allocated responsibilities and planning meet your requirements and is looking forward to a fruitful co-operation with MIT.

7.4 Acceptance and Signature

Done and signed in two original copies:

On behalf of MIT:

Date: .....

.....

On behalf of NLR:

Date: .....

.....

Appendix A: Facilities

NLR operates a Thermal Vacuum Laboratory for research on (aero)space thermal related issues. This laboratory is equipped with various data-acquisition systems, ranging from thermocouple, thermistor, platina type temperature sensor based systems to a 50 Hz infrared camera and vacuum/pressure measurement systems.

For the offered test the the Thermal Vacuum Space Simulator (Thermal-vacuum chamber). Its internal working space has a diameter of 0.9 m and a length of 1.5 m. The temperature is controlled to within ±2 K by means of gaseous nitrogen which circulates in a cylindrical shroud. The maximum heat load at -180°C is 500 W. One of the two chamber doors is equipped with a 0.25-m diameter quartz window, allowing the test items to be observed. Thermal Cycling tests can be performed using the thermal shroud and/or a heat sink.

Figuur 3: Thermal Vacuum Space Simulator

Specifications:

- **Shroud Temperature**
  Temperature range: -150 °C up to +150 °C
  Max. temperature rate-of-change: upslope 1.7 °C/min, down slope 3 °C/min
  Programmable temperature profiles

- **Heat sink Temperature (independent from shroud)**
  Temperature range: -100 °C up to +120 °C
  Max. temperature rate-of-change: upslope ~7 °C/min, down slope ~10 °C/min
  (depending on test item and I/F plate thermal mass)
  Programmable temperature profiles

- **Pressure**
  Ultimate vacuum: 2×10^{-7} mbar (=2×10^{-5} Pa) (depending on test item out gassing)

- **Dimensions and feed throughs**
  Useful dimension: 150 x 90 cm (length x diameter)
  Various feed through flanges, 2 ×10″, 2 × 4″
  One viewing glass (visible light or infrared)

- **Data acquisition**
  A separate, independent data-acquisition system is available for multi thermocouple (type-T) data logging, current maximum is 54 but expansion is possible. If required the system is easily expanded for voltage, resistance or current measurements

- **Other**
  Dry vacuum pump system, cryo pump for high vacuum

Appendix B: NLR General Conditions NLR for small and medium sized projects

General Conditions of the Stichting Nationaal Lucht- en Ruimtevaartlaboratorium (NLR) for assignments to NLR

1 Definitions

In these general conditions the following definitions apply;
Proposal: the description of the activities, the price, conditions, planning and delivery dates that NLR has offered to the Customer including changes thereof and additions thereto that have been agreed in writing.
Activities: the activities as described in the Proposal.
Results: results directly generated by the performance of the Activities that NLR delivers in accordance with the Proposal.
Customer: The party that has accepted the Proposal.

2 Applicability

(1) These general conditions are applicable if so stated in the Proposal or if stated in writing in any other way.
(2) Applicablity of general conditions or other conditions of Customer is expressly excluded.

3. Proposal and entering into force of agreement

(1) Unless otherwise stated in the Proposal, the Proposal is valid for 30 days after the date of dispatch mentioned on the Proposal.
(2) Customer may only use the information in the Proposal for evaluating the Proposal and not for any other purpose.
(3) Reproduction or disclosure of (parts of) the Proposal in whatever form is not permitted without written consent of NLR.
(4) The agreement enters into force on the date the written acceptance by Customer of the Proposal is received by NLR.

4 Activities

(1) The Activities are solely defined by the description thereof in the Proposal and by changes agreed upon in accordance with article 12(1).
(2) All delivery dates are determined by NLR to the best of its knowledge based on the information that was known at the time of issuing the Proposal. These delivery dates shall be observed in as far as possible. However, NLR will not be in default by the mere fact of its exceeding a delivery date without having been served written notice thereof.
(3) Unless otherwise stated in the Proposal, all deliveries are Ex Works Amsterdam or Marknesse in accordance with the Incoterms 2000.
(4) NLR is not obliged to start the Activities before the Customer has provided to NLR all goods and information to be provided, in the form, amounts and/or quality as agreed. If any delay is caused by late delivery thereof, the period referred to in article 4(2) shall automatically be extended and excess cost for NLR arising therefrom can be charged to Customer.
(5) NLR is entitled to replace employees performing the Activities by other employees. In case employees of NLR are mentioned by name in the Proposal, replacement shall take place after consultation with Customer.
(6) In case Activities are performed by NLR employees at the premises of the Customer, the Customer shall see to it that such employees shall receive suitable working space and office facilities.

5 Price

(1) If a fixed price is stated in the Proposal, this will be the agreed price.
(2) If no fixed price is stated in the Proposal, the price will be determined by costing on the basis of the rates determined by NLR. These rates can be revised at the beginning of each calendar year.
(3) if in the Proposal on the basis of costing a maximum price is stated, NLR is not obliged to perform the Activities in as far as the maximum price would be exceeded thereby. In such a case, NLR will timely consult with Customer.
(4)If a ROM price is stated in the Proposal, this price is an estimate of the costs without obligation for NLR.
(5) Unless otherwise stated in the Proposal, all prices and amounts stated by NLR are exclusive of Value Added Tax and other taxes and duties, package, transport, insurance and customs. These cost will be charged to Customer separately if incurred by NLR.

6 Payment

(1) Payment shall take place in accordance with the payment schedule stated in the Proposal. NLR will send invoices for each payment. Customer shall pay the invoices without discount or adjustment within 30 days after the invoice date in the currency stated in the Proposal.
(2) Customer can object to an invoice only within the term of payment. Objections do not suspend the obligation to pay.
(3) In case NLR and Customer have agreed that the Activities are to be performed in phases, NLR can suspend the Activities for the next phase until Customer has paid the price for the previous phase.
(4) In case of late payment, legal interest and the cost incurred by NLR for recovery of the late payment shall be charged to Customer.
(5) NLR is entitled to require securities such as a bank guarantee or a letter of credit. In case of delayed provision of such security, NLR is entitled to suspend the Activities.

7 Liability

(1) NLR's maximum liability to Customer whether in contract, tort (including negligence), breach of statutory duty or otherwise, arising under or in connection with the agreement for direct damages, suffered by Customer shall be limited to the total sums paid to NLR under the agreement or €500.000,=, whichever is less.
NLR is not liable for indirect or consequential damages.
(2)NLR is not liable for damage caused by:
a) defects of goods supplied to NLR that have been passed on by NLR to the Customer, in its entirety, processed or as component of the Result, in as far NLR is not able to recover such damage from its supplier.
b) force majeure, which includes illness or non-availability for reasons beyond control of NLR of an employee if in reason no adequate substitute can be found;

c) incorrect information supplied by Customer to NLR;
(3) NLR is not liable, and Customer indemnifies NLR and holds NLR harmless, from and against any and all claims from third parties for damages arising out of or in connection with or resulting from the use by or through Customer, of the Results from the Project unless caused by gross negligence or wilful intent of NLR.
(4) Customer is liable for damage of NLR and of persons employed by NLR during the Activities at the premises of Customer unless caused by gross negligence or wilful intent of NLR.

8 Warranty
(1) NLR warrants that NLR performs the Activities to the best of its knowledge according to the standards and state of the art at the time of issuing the Proposal.
(2) NLR will only warrant the correctness and the proper functioning of the Results if this is stated in the Proposal and for the period mentioned in the Proposal.
(3) The warranty enters into force at the moment the Results are actually at the disposal of Customer unless Customer has accepted the Results earlier. In that case the warranty enters into force at the date of acceptance.
(4) Notwithstanding possible warranties of a supplier, NLR gives no warranty for materials supplied to NLR that NLR passes on to Customer.
(5) The warranty shall lapse in case the defects are fully or partly caused by improper use, normal wear and tear, negligence of Customer, repair or maintenance by a third party or acting contrary to the instructions of NLR or in the event Customer has not ceased to use the Results after discovering the defect.
(6) Any warrantyclaims shall lapse in case they are not submitted in writing to NLR within three weeks after discovering the defect or after the defect could reasonably have been discovered.

9 Intellectual Property rights
(1) All intellectual property rights to the Results including the right to apply for a patent or other rights to the Results shall vest in NLR unless otherwise stated in the Proposal.
(2) Customer shall be granted a non-exclusive, full and free right to use the Results
(3) In case, according to the Proposal the intellectual property rights to the Results shall vest in Customer, those rights shall be transferred to Customer at the moment Customer has fully complied with its obligations. In such a case NLR shall be granted a non-exclusive, full and free right to use the Results.
(4) Any background information provided by NLR or Customer shall remain property of the party providing such information.

10 Property of goods
(1) In the event the Activities result in the delivery of a tangible good, (such as reports, drawings, equipment, etc), the ownership of such tangible good shall, notwithstanding article 9, be transferred to Customer at the moment Customer has fully complied with its obligations. The risk shall pass on to Customer at the moment such goods are actually provided to Customer.

11 Confidentiality and publication
(1) Data that are marked confidential by the disclosing party shall be kept confidential by the receiving party during five (5) years after receipt of the data.
(2) This duty of confidentiality shall not be applicable to:
a. data which are in the possession of the receiving party at the moment of receipt of the data;
b. data which are generally known;
c. data which have been legitimately obtained by the receiving party from third parties;
d. data generated by the receiving party without using the data of the disclosing party.
(3) Reports shall only be published by Customer unchanged, literally, in their entirety and stating the name of NLR, unless NLR has given written consent for a different form of publication.
(4) If Customer or NLR wishes to publish about the Activities, prior written consent of the other party is required. Such other party shall react in writing to a request for consent within thirty (30) days. Consent shall not be unreasonably withheld.
(5) NLR is entitled to disclose the Results internally.
(6) Customer is not entitled to use a report made by NLR fully or partly for submitting claims, undertaking legal actions or for advertising or for promotion in general without written consent or NLR.

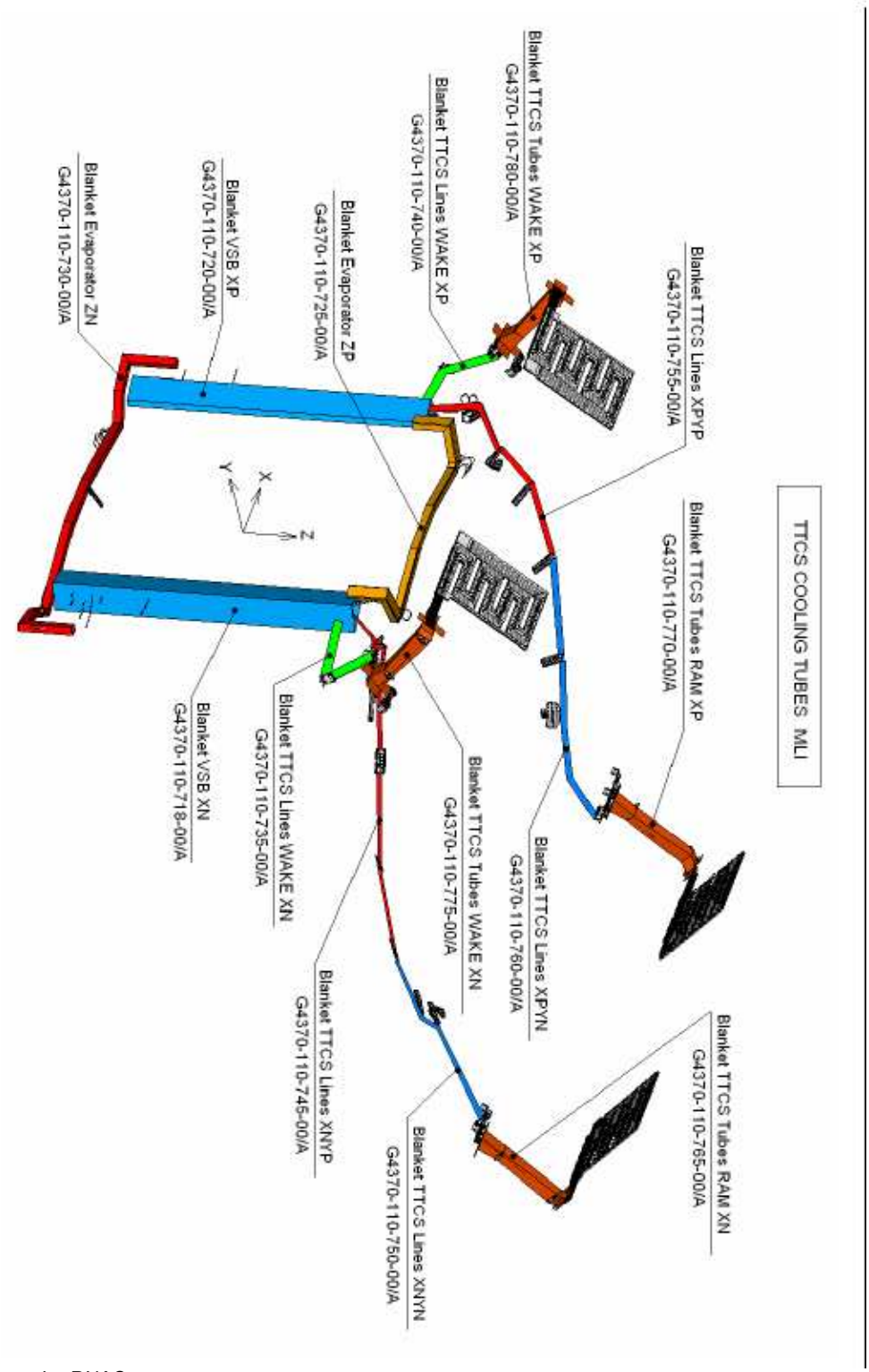
12 Changes
(1) Changes of and/or additions to the Activities and/or deviations of these General Conditions are binding only after written agreement between NLR and Customer.
(2) With respect to future agreements, the Customer will not be able to derive any rights from any deviations in the past.

13 Termination
(1) In case of default of Customer, if Customer is declared bankrupt, if a suspension of payment is requested or granted, or his company is transferred, closed down or liquidated or if an administrator or receiver is appointed for Customer, NLR can terminate the agreement in whole or in part, without taking the matter to court and without further notice of default, without prejudice to NLR's other rights,
(2) NLR can terminate the agreement if circumstances arise of such a nature that fulfilment of its obligations cannot reasonably be demanded.

14 Access
(1) If and in as far conditions imposed by Customer for access to buildings and/or premises of Customer contradict these general conditions, NLR is not bound to such conditions.
(2) Customer is obliged to comply with the conditions imposed by NLR for access to buildings and/or premises of NLR.

15 Disputes and applicable law
All disputes arising from the agreement that cannot be settled by mutual consultation shall be settled by the competent court of Amsterdam.
Dutch law is applicable to the agreement.

Appendix C: Overall TTCS MLI lay-out



Picture by RUAG.

WHAT IS NLR

The National Aerospace Laboratory (NLR) is the centre for Aerospace Research, Development, Test & Evaluation in The Netherlands

NLR is a non-profit organisation and employs over 700 people, the majority being academically trained professionals. The organisation is fully certified to handle complex aerospace development projects

NLR facilities include wind tunnels, flight- and ATM-simulators, two laboratory aircraft and many other accredited aerospace test facilities

***NLR** – Dedicated to innovation in aerospace*

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